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ANALYSIS OF AGRICULTURAL INNOVATION DYNAMICS IN RURAL AREAS: A CASE STUDY OF RICE PARBOILING IN THE MUNICIPALITY OF GLAZOUÉ IN BENIN, BETWEEN 2013 AND 2021

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ABSTRACT

Dynamics and magnitudes of innovation in the agri-food sector are rarely discussed in developing countries, including in the Republic of Benin. This article fills this gap by looking at these phenomena in the rice parboiling activity, between 2013 and 2021. It took as references, parboiling-related innovations inventoried under the project Joint Learning in Innovation Systems in African Agriculture (JOLISAA) between 2010 and 2013. Also, semi-structured and structured interviews were conducted with 103 women rice parboilers and six resource persons involved in rice parboiling in Glazoué, one of the rice production municipalities and poles in Benin. Quantitative analyses consisted of estimating frequencies, percentages, means, and standard deviations. Qualitative data were summarised in tables, figures, and quotations of significant utterances. Findings show that between 2013 and 2021, 8 innovations inventoried under the JOLISAA project in 2013, underwent up to 23 further technological and technical (65%), and organisational and institutional (35%) innovations. Each of these innovations took place over an average period of 2 years. 74% of these 23 innovations were developed by technical partners, compared to the 26% generated by the studied women rice-parboilers. Innovations from these women were predominantly incremental, while those from their technical partners were mainly modular in magnitude. Since modular, architectural, and radical innovations are generally the most profitable, strengthening the presence of technical partners or innovation brokering specialists could increase the dynamics of such innovations for the benefit of the target women. Findings also highlight the importance of continuous documentation which allowed to track as exhaustively as possible the innovations that occurred between 2013 and 2021 in rice-parboiling in the study area.

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INTRODUCTION

The dynamics and magnitude of innovation in the agri-food sector are rarely discussed together in developing countries, including the Republic of Benin. This article fills this gap by looking at the dynamics and magnitude of innovation in the rice value chain, and more specifically in the parboiling of locally produced rice, between 2013 and 2021. By dynamics, we mean changes over time (Bernard and Torre, 1994; Kouevi et al., 2023), and by magnitude or amplitude, we mean depth or width

(Henderson and Clark, 1990). According to Henderson and Clark (1990), there are four types of depth of innovation: incremental (i.e. very few changes in components and links among the components); architectural (i.e. very few changes in components but major changes in links or architecture or arrangement among the components); modular (i.e. major changes of components and very few changes of links among the components); and radical (i.e. major changes of components and links among components). Rice parboiling is one of the post-harvest rice activities in which innovations have been introduced over time to overcome constraints encountered by concerned stakeholders. It is a rice processing technique involving the rehydration, heating, and drying of paddy before milling (Houssou et al., 2016). This method yields rice with superior physical, organoleptic, and nutritional quality compared to white rice (Ndindeng et al., 2015). However, poor steeping resulting from inexperience or other factors can not only negate the mentioned advantages but also diminish the nutritional value of the rice.

Before the 2000s, the steeping method used in the Glazoué municipality produced low-quality rice containing sand, molds, broken, and charred grains, often with an unpleasant smell and uneven pre-cooking (Floquet, 2012). To address this issue, innovations were introduced along the steeping process chain (Dossou, 2015; Hinnou, 2013). These innovations aimed to make good-quality locally parboiled rice, available in Benin market.

In 2013, the JOint Learning about Innovation Systems in African Agriculture (JOLISAA) project, funded by the European Union and implemented in Benin, Kenya, and South Africa from 2010 to 2013, took stock of these rice parboiling innovations and traced their development up to 2013. As earlier mentioned, building on this knowledge stock of JOLISAA, the study from which this paper derives, aimed to identify and analyse the dynamics and amplitude of the innovations that the technologies inventoried under JOLISAA in 2010-2013 underwent between 2013 and 2021. Such a study will allow rice parboiling promoters to know the extent to which, how, and how often stakeholders innovate in Benin's second most important food value chain, at least over the study period (FAO, 2022; Gogan et al., 2018; MAEP, 2011; Seck et al., 2010), and, hence, to refine if necessary, their interventions.

Following this introduction, the remainder of this article successively addresses the research methodology, the findings, then the discussion and conclusion.

METHODOLOGY

This section describes and justifies the choice of the study area, and then, addresses the sampling and data collection, processing, analysis, and discussion methods.

Study area and sampling

The study took place in central Benin, in the Collines department or region, and more specifically in the municipality of Glazoué (see Figure 1). This municipality covers an area of 1,750 km2 (1.5% of the total area of Benin) and has a population of 717.477 (i.e. a density of around 52 inhabitants per km2) (RGPH4-2013). It lies between latitudes 7°50 and 8°30 North and longitudes 2°05 and 2°25 East.

Agriculture is the main source of income for 85% of the municipality's population. It is an extensive form of agriculture, characterised by low crop yields that are dependent on weather change risks, and by little use of modern production techniques (Afrique Conseil, 2006). The crops produced include cereals (maize, rice, sorghum), roots and tubers (cassava, yams), and pulses (cowpeas, soya, voandzou, pigeon peas) (Afrique Conseil, 2006). The main reason for choosing *Glazoué* for this study lies in the fact that it is one of Benin's two rice-growing development poles (MAEP, 2017). This rice cluster in central Benin brings together "lowland" and "upland" rice-growing systems and has agroecological potentials that suit well, diversified rice production. Furthermore, the population from this area has been exposed to rice parboiling technologies in the past and the women in the region were used to parboiling practices. Concerning the choice of survey units, the women rice-parboilers were selected from a list of 166 women rice-parboilers unequally distributed in 13 village cooperatives. 103 women rice parboilers, representing a sampling rate of 62%, were then randomly selected for this study.

Data collection

Data were collected in two main stages. The first stage consisted of consulting documents (reports, articles, briefing papers) from the JOint Learning in Innovation Systems in African Agriculture (JOLISAA) project and other sources, followed by semi-structured individual

interviews with six (6) resource persons from the project, and involved in rice parboiling in the study area. Information gathered at this stage was used to inventory the rice parboiling innovations documented under the JOLISAA project up to 2013. During the second stage, structured individual interviews were conducted with women who process paddy rice into parboiled rice (parboilers or women rice-parboilers) using a questionnaire. During these interviews, socio-economic data were collected on the profile of each respondent (age, level of education, family situation, ethnic group, and main activity). The individual interviews also provided information on the changes (or innovations) that the innovations documented by JOLISAA underwent between 2013 and 2021, as well as the years, reasons, and authors of these changes. These data were enriched with visits and participant observations in units processing paddy rice into parboiled rice, and in cooperatives, and also with the collection of illustrative photographs.

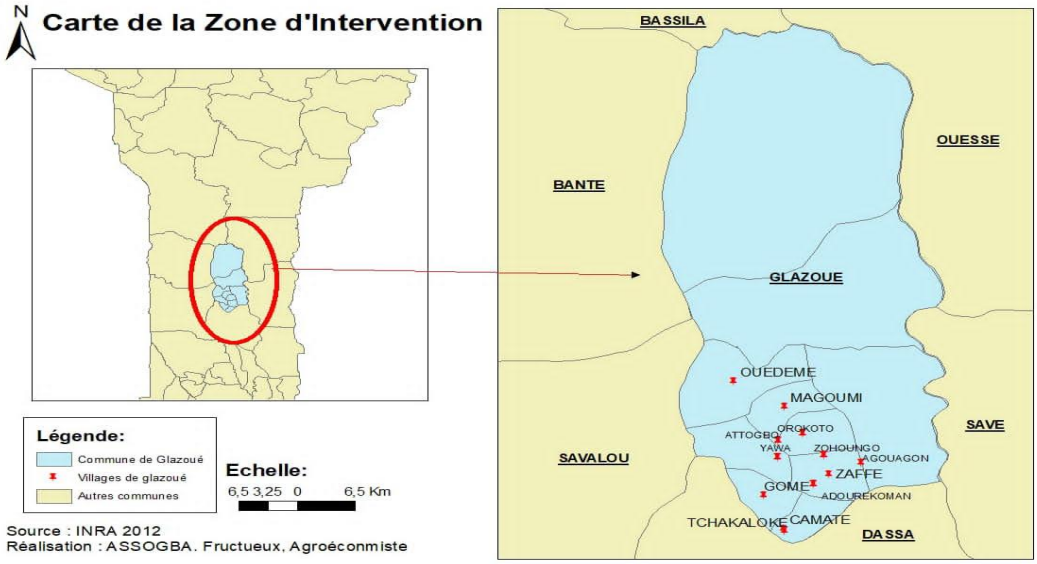

Figure 1. Map of the municipality of GLAZOUE
Source: INRA (2012)

Data treatment, analysis, and discussion

The various data collected were transcribed or entered into a database designed with Microsoft Excel 2016 software. They were then grouped according to the information deemed relevant for this article. Frequencies, percentages, means, and standard deviations were estimated and used to analyse the data. The data are also summarised in tables, whose contents are analysed and interpreted. Stories narrated by the respondents about the innovation process are summarised to support the data where this is deemed necessary.

Quotes are inserted to highlight significant utterances from the parboilers. In the discussion of the results, the data are interpreted in the light of general trends and of existing innovation, innovation dynamics, innovation amplitude, and rice-parboiling literature, among other things.

RESULTS

This section presents the socio-demographic characteristics of the respondents, as well as the dynamics of innovation around rice parboiling.

Socio-demographic characteristics of the women rice-parboilers surveyed

The socio-demographic characteristics of the respondents taken into account in this article are age; number of years of experience in rice parboiling; household size of respondents; respondents' level of education; the place of parboiling in respondents' income-generating activities; and their access to technical and financial supports. These characteristics are considered influential in the quality of the information provided by the respondents (Table 1). According to Table 1, the respondents are relatively young, but sufficiently experienced in rice parboiling

(average of 13 years) to provide valid information for the 2013-2021 study period. Besides, parboiling is their main agricultural activity and source of income.

Innovations documented in 2013 under JOLISAA

Table 2 below shows the rice-parboiling-related innovations documented under the Joint Learning in Innovation Systems in African Agriculture (JOLISAA) project in the study area in 2013. Analysis of Table 2 shows that seventeen innovations were documented under the JOLISAA project by 2013.

These innovations are grouped into four categories, namely genetic or varietal innovations, technological and technical innovations, institutional and organisational innovations, and mixed innovations. The table also indicates that technological and technical innovations predominated (53% or 9 out of 17), followed by institutional and organisational innovations (29%), genetic innovations (12%), and mixed innovations (6%).

Table 1. Socioeconomic characteristics of the surveyed rice parboilers (N=103).

Characteristics	Descriptive statistics
Age of respondents (year)	Minimum = 22; Maximum= 74; average=42±11
Experience in rice parboiling (year)	Average= 13±6.38
Household size	Average=6±1.75 people (minimum=3; maximum=12)
Marital status (%)	91.26% married
Education (%)	42.72% no formal education, 41.75% primary school, 15.53% secondary school
The main activity in the agricultural sector (%)	60.2% parboiling
Monthly income contribution from parboiling	Average of 67.8%
Importance of rice parboiling as an income source	A significant source of income for 60.2% of respondents
Support received from financial and technical partners	84.7% received support at least once
Types of support received	Equipment donations (67%); training and extension services (68.93%); cooperative registration (4.85%); connecting with companies for contractual relationships (18.45%)

Source: Field data, 2022

Table 2. Innovations documented under JOLISAA in 2013.

No.	Innovations documented in 2013	Illustrations
A	**Genetic or varietal innovations**	
1.	Improved variety IR 841	-
2.	Improved variety Nerica	-
B	**Technological and technical innovations**	
3.	Improved rice parboiling process	-
4.	Improved steaming equipment (galvanised sheet metal kettle plus bucket)	  (Kpossilandé, 2022, from the field)
5.	Use of akassa or maize paste to close orifices to prevent evaporation	-
6.	Improved hearth	 Source: (Zossou and Wanvoekè, 2010)

7.	The device is made of a pot and a bowl	 Source: (Zossou and Wanvoekè, 2010)
8.	The device is made of a pot and a strainer in aluminum	 Source: (Zossou and Wanvoekè, 2010)
9.	The device is made of a cooking pot, a basket, and a loincloth	 Source: (Zossou and Wanvoekè, 2010)
10.	Device made of a pot and sticks	 Source: (Zossou and Wanvoekè, 2010)
11.	Device made of a pot and a container placed in the bottom of the pot	 Source: (Zossou and Wanvoekè, 2010)
C	**Institutional and organisational innovations**	
12.	Rice-parboiling in women's group	
13.	Purchase of steaming equipment in group	
14.	Linking women with microfinance institutions and rice hulling groups	
15.	Hiring improved steaming equipment	
16.	Grouped presentation of parboiled rice at annual fairs in areas concerned	
D	**Mixed innovations (technological, technical, and organisational)**	
17.	Using training videos to disseminate rice-related innovations	

Source: Literature and field data, 2022

Between the year in which they were documented (2013) and the year in which the present study was conducted (2021), limits were identified in these innovations to the extent that some of them (8 out of 17, i.e. 47%) were still subjected to further refinements, incremental (i.e. very few changes in components and links among the components) or modular (i.e. important changes in components but very few changes in links among the components) innovations (based on Henderson and Clark (1990)'s classification). These happened to the technological innovations (improved parboiling device and process, and improved parboiling hearth), and the organisational innovations (group parboiling by women, rental, and purchase of steaming equipment in the group, grouped presentation of parboiled rice at fairs, and linking women rice-parboilers with microfinance institutions). Among the innovations that have not changed were: the IR841 variety, the New Rice for Africa (Nerica) variety, and adaptation innovations independently developed by the respondents themselves.

Limits and subsequent innovations undergone by those documented in 2013

This section presents, on a case-by-case basis, limits identified to the innovations documented in 2013 under the JOLISAA project, as well as the innovative responses to these limits and their authors. It shows that 47% (i.e.

8 out of 17) of the innovations documented in 2013 underwent various innovative changes over the following eight years.

Case of the improved 180kg and 300kg rice-parboilers

The JOLISAA project inventoried two types of rice parboiling devices. The first one, of 25kg and 45 kg of parboiling capacities, was composed of a cast aluminum pot and a frustoconical steaming tank made of galvanised metal sheet which is a bucket-shaped container whose bottom and lower 1/3 perimeter is perforated. The pot is adapted to the steaming tank in such a way that the perforated lower part of the tank is well inserted into it (Zossou and Wanvoekè, 2010). Next, from 2010 to 2013, to respond to new needs expressed by rice processors or parboilers, the National Agricultural Research Institute of Benin (Institut National de Recherches Agricoles du Bénin (INRAB)) increased the size of the system by introducing new high-capacity treatment components.

These higher-sized devices could treat 180kg, 270kg, and 300kg of paddy rice in two (02) hours. They were equipped with improved hearths to reduce smoke, but also to save firewood. Some shortcomings were identified by the rice parboilers after the use of medium-capacity (180kg) and large-capacity (300kg) parboilers (see Table 3 below). To help the parboilers overcome these shortcomings, innovations were introduced, as described in Table 3.

Table 3. Innovations induced by the limits of the improved parboiling system

No.	Limitations identified on the improved parboiling devices	Authors who identified the limits	Innovations driven by the limits and period		Authors of innovations
			Innovation	Year	
1	The device is too high, making it difficult to check the cooking stage of the rice during parboiling.	Women rice-parboilers	Grain quality-enhancer, Energy efficient, and Durable Material (GEM) system: Industrial equipment consisted of a soaking kit, a hot water pump, a steel steaming tank, a steel drainer, and a pulley system	2015	AfricaRice
2	No soaking kit (soaking is done separately)	AfricaRice			
3	Early appearance of rust and corrosion	Women rice-parboilers			
No.	Limits identified on the GEM system	Authors who identified the limits	Innovations driven by limits and period		Authors of innovations
			Innovation	Year	
1	The GEM system is stationary (cannot be moved)	Women rice-parboilers	A device composed of a paddy soaking and steam pre-cooking chamber. This device, unlike the initial GEM system, can be easily moved from one location to another	2018	Food Security through Agricultural Intensification Project (PSAIA)
2	High installation costs	Women rice-parboilers			

Source: Literature, and field data, 2022

As summarised in Table 3, in 2015 the AfricaRice research centre and its partners developed the "Grain quality-enhancer, Energy efficient and Durable Material (GEM)" as an advanced rice-parboiling device. The integrated multifunctionality of this device made people consider it as a system. The initial GEM launched in 2015, is immobile and expensive to install (around 2,000,000 fcfa or about 4,000 USD), whereas women rice-parboilers used to spend about 55,000 fcfa (i.e. about 110 USD) to access the above-mentioned 45 kg device.

Given this mobility constraint, the initial GEM device could be installed only at the final treatment and rice distribution centre (*Centre de Traitement Final et de Distribution de riz (CTFD)* of the regional union of Women rice-parboilers of central Benin *(Union*

Régionale des Femmes Etuveuses du Centre (URFER-C). Only 16.50% of the respondents mentioned that they had been able to access this initial GEM system. The immobility feature of the initial GEM led the Food Security through Agricultural Intensification Project (PSAIA) in 2018 to introduce the improved GEM system consisting of an improved hearth, and a paddy soaking and steam pre-cooking chamber. Unlike the initial GEM system, this improved GEM can be easily moved from one location to another. 13.59% of the study respondents could access this improved GEM. Figure 6 illustrates the evolution of the improved rice-parboiling system between 2010 to 2021.

Improved rice parboiling process

60% of the surveyed women rice parboilers said that they changed and added certain operations in their way of processing rice since the arrival of the GEM system in 2015 (see Table 4). These results confirm those of Dossou (2015), who showed that triple washing, sorting, and winnowing are new parboiling steps recommended after the introduction of the improved GEM system.

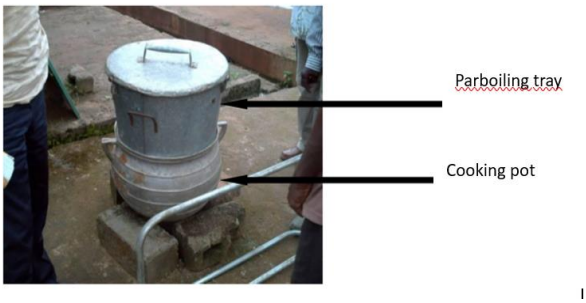

Figure 2. Improved rice parboiling system (parboiling kit) (Zossou et Wanvoekè, 2010)

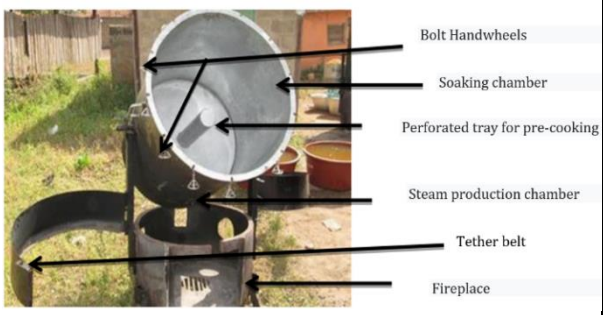

Figure 3. 180kg parboiling kit (KIT 180-rice) (Houssou et al., 2016)

Figure 4. A GEM parboiler with a capacity of 600 kg of rice per day (TAAT, 2021)

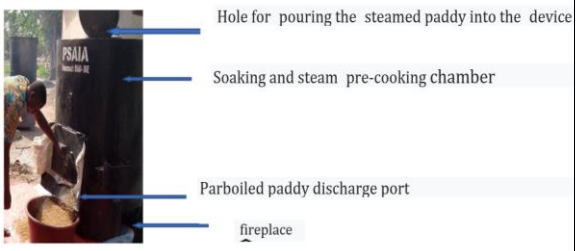

Figure 5. Improved steaming system introduced by the Food Security through Agricultural Intensification Project (PSAIA) (Kpossilandé, 2022)

Figure 2-5. Evolution of the improved rice-parboiling devices over time.

Table 4. Innovations induced by the limits of the improved parboiling processes.

N°	Limits identified to the improved parboiling process	Authors who identified the limits	Innovations driven by limits and period		Authors of innovations
			Innovation	Year	
1	Long soaking and drying times which increase the rate of	Women rice-parboilers	-Soaking time reduced from 24 hours to 12 hours -Drying time reduced from 8h to 4h	2015	Women rice-parboilers

	breakage of parboiled rice grains after hulling				
2	Presence of impurities (sand, grasses, and unripe grains) in the rice after parboiling	AfricaRice	Addition of new operations such as: weighing the rice at the start and the end of parboiling; winnowing, sorting, and triple washing of the paddy at the start of parboiling.	2015	AfricaRice
3	Non-compliance with hygiene rules while parboiling	NGO *Levier pour le Développement Local Durable (LDLD)*	Introduction of certain hygiene rules in the parboiling process. These include: covering hairs, avoiding nail varnish, wearing gloves and a smock, avoiding jewelry, keeping the parboiling environment clean, etc.	2018	NGO Levier pour le Développement local Durable (LDLD)

Source: Literature, and field data, 2022

According to Table 4, the women rice-parboilers have reduced the time taken for soaking and drying. The soaking time was reduced by 31.07% of the respondents, according to whom this change reduced unpleasant smells and mould in the parboiled rice. 45.63% of women surveyed also reduced the time they spend drying parboiled paddy under the sun. According to the respondents, this change reduces the breakage rate (to less than 65%) of grains at hulling. They argued that the longer the solar drying time (8 hours or more), the more easily the grains break during hulling. This is what Odette, President of the parboilers' union (URFER-C), explains in the following statement:

Box 1: *« When the parboiled paddy rice spends 24 hours or more under the sun, during the hulling, you can end up with 65 kg of broken grains and only 35 kg of long grains after calibrating, out of 100 kg of parboiled paddy. Meanwhile, broken grains and long grains are not sold at the same price on the market. Broken rice is sold for lower prices than long-grain rice and this is a loss for us. »*

Furthermore, the respondents said that "to ensure that the rice grains dry perfectly, the solar drying time is reduced and the shaded drying time is increased". Some parboilers added weighing the rice at the beginning and end of parboiling (23.30% of respondents), winnowing (58.25% of respondents), sorting (23.30%), and triple washing (77%) of the paddy at the beginning of parboiling, as new operations in the rice parboiling process. For them, winnowing, sorting and triple washing removes impurities (sand, debris, straw, etc.), and unripe grains from the paddy. Most of the women rice-parboilers who added these operations said they learned them during group parboiling occasions organised by their union (*Union Régionale des Femmes étuveuses de riz du Centre (URFER-C)*. According to them, these operations significantly contribute to improving the quality of parboiled rice. For the respondents, weighing enables them to know the exact quantity of paddy they are parboiling, which makes it easier for them to assess losses at the end of the parboiling process. Furthermore, the introduction of hygiene rules into their practices was confirmed by 10.7% of the surveyed women.

Introduction of improved hearth

The JOLISAA project identified two improved hearths: the improved clay hearth and the improved metal hearth directly integrated into the 180kg and 300kg parboiling devices earlier mentioned. The improved clay hearths have a more concave shape than the simple traditional or initial ones (see Figure 7 below). This reduces the spread of smoke during steaming. It was introduced by INRAB. Two main changes occurred to the improved hearths. These are the introduction of the hearth integrated into the GEM system (Figure 8), and the introduction of the metal rice husk hearth (Figure 10) (see Table 5).

As shown in Table 5, in 2015 AfricaRice introduced a new hearth through the initial GEM system. Designed with small red clay bricks, it was one of the components of the initial GEM system. This hearth helps to reduce the risk of burning and exposure to smoke for the women

during the parboiling processes. Later on, this clay hearth was replaced by easily movable rice husk metal hearth. This mobile metal hearth was experienced by only 7.76% of the women surveyed. It was introduced, first, as a solution to the constantly growing cost of firewood attributed to deforestation and wood scarcity; and secondly, because firewood produces excessive smoke, which blackens the containers used during the parboiling process. According to Sabiyo *et al.* (2020), rice husks are cost-efficient compared to firewood. Zossou and Wanvoeke (2010) also stated that the improved hearths were designed to save energy and protect the environment, but also to improve thermal efficiency. Meanwhile, the respondents highlighted that rice husk metal hearths are very dirty, as mentioned in the following utterance from Mrs Odette:

Box 2: « *When you use rice husk fire to parboil or even to cook, it produces a lot of black debris, and every time the wind blows, this debris spreads all over your house.* »

Group parboiling and group purchase of parboiling equipment

Group parboiling is a practice that has existed since the 2000s and it was documented in 2013 as an organisational innovation under the JOLISAA project. Improvements undergone by this form of organisation between 2013 and 2021 are summarised in the following Table 6.

Table 5. Innovations induced by the limitations of the improved rice parboiling kiln.

No	Limits identified to the metal hearths of the 180kg and 300kg devices	Authors who identified the limits	Innovations driven by limits and period		Authors of innovations
			Innovation	Year	
1	High firewood consumption	Women rice-parboilers	Hearths powered by a solar fan and fuelled by rice husks, a free and abundant fuel in rice-growing regions (hearth integrated into the "GEM" system).	2015	AfricaRice
2	Gives off too much smoke	Women rice-parboilers			
No	Limits identified to the hearth integrated into the GEM system	Authors who identified the limits	Innovations driven by limits and period		Authors of the innovation
			Innovation	Year	
1	Immobile hearth (difficult to move)	Women rice-parboilers	Easily movable rice husk metal hearth independent of the « GEM » system	2017	Programme for the promotion of Women's Entrepreneurship in the Rice Sector *(Programme d'Appui à l'Entreprenariat Féminin au sein de la Filière Riz)* (PAEFFR-Benin)
No	Limits identified to the easily movable rice husk metal hearth	Authors who identified the limits	Innovations driven by limits and period		Authors of the innovation
			Innovation	Year	
1	Produces a lot of debris	Women steamers	**-**	**-**	**-**

	and dirty the parboiling workplaces	

Source: Literature and field data, 2022

Figure 7. Improved hearth documented in 2010 (Zossou et Wanvoekè, 2010)

Figure 2. Improved hearth directly integrated to the improved 180 kg device (Kpossilandé, 2022)

Figure 10. Improved rice husk metal hearth (Kpossilandé, 2022)

Figure 9. Improved hearth integrated into the GEM system (Dossou, 2015)

Figure 7-10 illustrates the evolution of the improved hearths over time.

Table 6. Innovations induced by the limits of group parboiling.

N°	Limits identified	Authors who identified the limits	Innovations driven by limits and period		Authors of innovations
			Innovations	Year	
1	Low level of representation and strategic positioning of parboilers' cooperatives within the rice sector	*Collines* Rice Producers and Processors' Union (UNIRIZ-C) with the help of VECO-WA	Creation of the Central Benin region Union of Women rice-parboilers (*Union Régionale des Femmes Etuveuses du Riz du Centre)* (URFER-C)	2014	Women rice-parboilers with support from VECO-WA NGO
			Bringing village groups of rice-parboilers to conform to the cooperative creation rules of the Organisation for the Harmonisation of Business Law in	2014	Women rice-parboilers with support from VECO-WA NGO

			Africa (OHADA) (Ordonnance No. 59/PR/MDRC)		
			Participation of village cooperatives in the collective parboiling activities of URFER-C	2015	The Women's Union (URFER-C)
2	Poor management and organisation of activities	Program for the promotion of Women's Entrepreneurship in the Rice Sector (PAEFER)	Creation of two sub-groups within each village cooperative, and alternation among the sub-groups for parboiling activities	2018	Women rice-parboilers
			Use of tools such as visit logs and sales monitoring logs	2020	PAEFER of LDLD-NGO

Source: Literature and field data, 2022

As mentioned in Table 6, in 2014, the *Union Régionale des Femmes Etuveuses de Riz du Centre* (URFER-C) helped its village-level groups of cooperative women parboilers (Ordonnance No. 59/PR/MDRC) to comply with the requirements of the Uniform Act of the Organisation for the Harmonisation of Business Law in Africa (OHADA) related to the rights of cooperative societies. In 2015, with the help of AfricaRice, URFER-C installed a parboiling complex at the *Glazoué* Final Rice Processing and Distribution Centre (CTFD). URFER-C organises collective parboiling activities in this centre. Activities completed in CTFD centre consist of purchasing paddy rice from farmers during periods of abundance and making the rice parboiled by the village-level cooperatives that are members of the URFER-C.

Box 3: « In the past, when we participated in the parboiling of rice at the CTFD, we were paid 10% of the revenue generated by the quantity of rice processed. Later on, we refused this payment modality because it was not convenient for us since we traveled from our respective villages to the CTFD, which is located in the Glazoué centre. Therefore, we requested that when the rice we parboil are sold, the net profits should be used to pay us. To give you an example, when my cooperative parboils a ton of paddy at the CTFD, after the sale, URFER-C takes away every money it has spent and leaves for us the profit, which we share among ourselves.

The village cooperative members were initially paid with 10% of the income generated by the parboiling activities. However, following claims from the women, the union (URFER-C) changed the payment rule and now equitably shares the net profit generated by the parboiling activity among those who complete the processing. 80% of this study's respondents participate in the parboiling activities organised by the union. Mrs. Cyprienne, president of the Glazoué Communal Cooperative, explains the operating mechanism of the union in Box 3. Other organisational changes in village parboilers' cooperatives include the use of management tools such as sales monitoring notebooks (27.67% of cooperatives) and the formation of two sub-groups within some cooperatives (5.82%) for alternation of collective parboiling activities. Subgroups creation and alternation of group works contributed to the reduction of parboiling work burdens, and to free time for the women parboilers for other personal activities. Management documents adopted make it possible to monitor and ensure transparency of activities within the cooperatives.

Linking women rice-parboilers with microfinance institutions and rice hulling organisations

There was no major change to this innovation during the study period (2013-2021). This is mainly because very few (10.68%) women rice-parboilers benefited from micro-credit during the considered period. However, 2.91% of these women said that they switched from obtaining loans from formal microfinance institutions to traditional saving (*tontine*) groups within village cooperatives between 2015 and 2017. For these women, this change eliminated administrative hassles usually involved in applying for loans from formal microfinance institutions.

Presentation of parboiled rice at annual fairs

Since 2014, women parboilers no longer present parboiled rice individually at fairs in central Benin, but through their union (*Union Régionale des Femmes Etuveuses du Centre (URFER-C).* As part of its activities,

the URFER-C supports women parboilers through the final processing of parboiled rice and group marketing. Rice parboiled by the women is husked, calibrated, and packaged in attractive packaging at the rice treatment centre (CTFD) under the label *"Saveur des Collines"*. This brand of parboiled rice represents all the rice parboiled in the *Collines* region at annual fairs.

Use of akassa or maize paste to seal steam leakage orifices

The use of *akassa* or *maize paste* to close steam leakage holes is a practice changed by 49.51% of women parboilers. 20.38% of them switched from using *akassa* or *maize paste* for steam leakage ways sealing to using cassava flour mixed with water. These women said that when water and cassava flour are mixed, they form a very sticky paste, and once this mixture is applied to leakage ways, it can last for many months. Respondents also mentioned the use of white loincloth (16.5%) and rice husks (7.76%) for the closing of leakage ways since 2015. In their view, the loincloths hold smokes better and allow them to avoid food (akassa and cassava flour) waste.

Synthesis of the findings

Table 7 below gives a synoptic view of the study results and is intended to facilitate the discussion presented in the following section.

DISCUSSION

As shown in the results, eight (8) of the seventeen (17) rice parboiling innovations identified in 2013 under the JOLISAA project underwent up to twenty-three (23) technological and technical innovations, followed by organisational and institutional innovations, between 2013 and 2021, i.e. in nine (9) years. From the analysis of this synthesis table, we derived the following discussion points.

Absence or scarcity of genetic or varietal innovations

According to the findings, no innovative changes occurred in the two rice varieties used in the study environment in almost a decade (2013-2021). This result is not surprising, as it is well known that the varietal selection process can take a relatively long time. According to Clavel in 2001, it often takes 12 to 15 years for research to come up with a new variety. Most specifically, according to Brar and Virk (2010), with traditional techniques, the development of a new rice variety can take up to 10 years.

Apparent disappearance of certain innovations

The use of rice training videos, experienced by some of the respondents, seems to be disappearing from their habits over the years. This can be explained either by the obsolescence of the content of the videos or by the fact that the women surveyed had already perfectly understood and memorised the content. This result may also be explained by the inability of the women to keep and use the videos due to a lack of suitable equipment and/or electric power sources; or by the fact that the organisations that disseminate the videos would have stopped promoting them (Assogba, 2013).

Predominance and average two-year frequency of technological and technical innovation

Of the 23 innovations recorded between 2013 and 2021 (see Table 7 above), 15 (or 65% or 2/3) are technological and technical. These innovations were recorded with an average frequency of around 2.27±0.8 years, with 2 years and 5 years respectively as the minimum and maximum (taking 2013 as the year in which they were developed). This predominance and relatively close frequency of technological and technical innovation indicates the extent to which women would have been facing technological and technical challenges in rice parboiling in the study area, which is representative of central Benin.

Importance and average two-yearly frequency of organisational and institutional innovations

As Table 7 in the previous section shows, 8 of the 23 innovations (i.e. 35% or 1/3) identified between 2013 and 2021 were organisational and institutional. These innovations occurred with an average frequency of about 2.3±1.8 years, with 1 year as the minimum and 6 years as the maximum (considering 2013 as their year of development). This result also indicates the extent to which women would have been facing organisational and institutional challenges with almost the same frequency as technological and technical innovations, which confirms the work of several authors who showed that organisational innovations are adopted under the impetus of technological innovations (Ayerbe, 2006; Wischnevsky *et al.*, 2011).

Table 7. Summary of innovations in rice parboiling between 2013 and 2021 according to respondents from the commune of Glazoué.

N°	Innovation category	Innovations RPI-2013 identified in 2013	Innovations undergone by RPI-2013 between 2013 and 2021			Authors of diagnoses	Authors of innovations	Time taken to innovate (year)	Type (amplitude) of innovation
			Change undergone	Component concerned	New product obtained				
1.	Genetic or Varietal	IR-841	-	-	-	-	-	-	-
2.		NERICA	-	-	-	-	-	-	-
3.	Mixed	Extension with training videos	Disappearing from habits	-	-	-	-	-	Incremental
4.	Technological and technical	Improved parboiling device	Development of an integrated parboiling system	All components	Immobile GEM system	Parboilers	AfricaRice	2	Radical
5.			Adding components	Pulley system (missing)	Pulley system	Parboilers	AfricaRice	2	Modular
6.				Hot water pump (missing)	Hot water pump	AfricaRice	AfricaRice	2	Modular
7.				Soaking kit (missing)	Soaking kit	AfricaRice	AfricaRice	2	Modular
8.				Clay bricks hearth fuelled with smoking firewood	Integrated, immobile rice husk metal hearth	Parboilers	AfricaRice	2	Modular
9.				Soaking and pre-cooking chamber (missing)	Soaking and pre-cooking chamber	Parboilers	PSAIA	3	Modular
10.			Change/replacement of components	Oxidizable sheet metal used for tray and drainer	Stainless steel sheet	Parboilers	AfricaRice	2	Incremental
11.				Integrated and immobile rice husks metal hearth	Mobile rice husk metal hearth	Parboilers	PAEFR-Bénin	2	Incremental
12.			Changing consumables/inputs	Expensive and smoking firewood	Cheap and low-smoking rice husks	Parboilers	AfricaRice	2	Modular
13.				Use of *akassa* and maize paste for steam leakage proofing	Use of cassava flour paste, white loincloth, or rice husks	Parboilers	Parboilers	2	Modular
14.		Processes	Changes in operating time and quality	Soaking time (24 hours long)	Time reduced to 12h	Parboilers	Parboilers	2	Incremental
15.				Solar drying time (8 hours)	Time reduced to 4h	Parboilers	Parboilers	2	Incremental
16.				High breakage rate (up to 65%)	Reduced breakage rate (<65%)	Parboilers	Parboilers	2	Incremental
17.			Addition of	Impurity rate (high)	Weighing, winnowing,	AfricaRice	AfricaRice	2	Modular

			operations		sorting, triple washing			
18.				Hygiene measures (absent)	Covering hairs, and nails without varnish, wearing gloves and smocks, no jewelry, cleaning the work area	LDLD	LDLD	5	Modular
19.			Restructuring	Representativeness (low)	Creation of the Regional Union of Women Rice Parboilers of Central Benin (URFER-C)	Parboilers with the help of VECO-WA	VECO-WA	1	Modular
20.				Cooperative status (absent)	Compliance with OHADA cooperative standards	VECO-WA	VECO-WA	1	Modular
21.	Organisational and institutional	Isolated village groups of women parboilers	Management of cooperative life, human resources, activities, and time	Parboiling activity completion (non-collective)	Group parboiling		URFER-C	2	Modular
22.				Marketing (non-collective)	Group marketing with a brand or label		URFER-C	1	Modular
23.				Participation in major events (non-collective)	Group participation (to fairs) via URFER-C	URFER-C	URFER-C	1	Modular
24.				Building on group potential and time (weak)	Subdivision into sub-groups and division of tasks in time and space	PAEFER	Parboilers	4	Modular
25.				Management tools (absent or inadequate)	Adoption of new management tools (logbooks, etc.)	PAEFER	PAEFER/LDLD	6	Modular
26.		Access to microfinance services	Access to financial resources	Access to formal microcredit (difficult and weak)	Access to microcredit via local savings and loan groups (easier)	Parboilers	Parboilers	2	Modular

From this perspective, Ezzaoui (2014) states that "when organisational innovation is integrated, it is generally to examine the organisational designs likely to support technological innovation, particularly product innovation". After deep analysis, one may realise that every effective innovation occurs systemically and also often functions systemically (Battisti and Iona, 2009; Schmidt and Rammer, 2007).

Mixed origin of diagnoses leading to innovations

Table 7 shows that the majority of diagnoses leading to innovations (12/23, or 52% of cases) came from both the women' surveyed and their partners. Meanwhile, 6 of the 23 diagnoses (26%) came essentially from the technical and financial partners of the women's groups. These findings indicate the extent to which the women are aware of the challenges they face and communicate effectively with their partners to resolve them. The results also show the extent to which the technical partners involve their beneficiary women in the process of resolution of the challenges they face and express. One can observe that challenges identified mainly by the technical and financial partners seem technically more complex than the diagnosis skills of the women parboilers. For example, it may have been difficult for women parboilers to identify the lack of a hot water pump as a challenge. The same applies to routine challenges that are barely perceptible to the women parboilers, such as those relating to hygiene and impurities, which only feedback from those who care about hygiene and cleanness, such as consumers and technical partners, can enable them to perceive.

Predominant external origin of innovators

According to the content of Table 6, 17 (74% or 3/4) of the 23 innovations identified were developed by the technical partners of the women parboilers, compared with 6/23 (26% or 1/4) by the women parboilers. These results indicate the importance of technical expertise or technical and technological skills in the development of technological, technical, organisational, and institutional innovations. Thus, one can observe that innovations emanating from the women parboilers are essentially technological, technical, organisational, and predominantly incremental.

In other words, innovations coming from the target women are of small amplitude and low technical constraint, and therefore they are developed without much effort for the change of their routines or habits. The other innovations from the technical partners are mostly modular in scope.

Predominance of modular innovations

17 out of 23(74%) of the innovations identified between 2013 and 2021 were modular in amplitude. This means that these innovations involved major modifications to components, and lesser modifications to the links among or the arrangements or architectures of these components (Henderson and Clark, 1990; Lecossier *et al.*, 2016).

Importance of ongoing monitoring, evaluation, and documentation of innovations

The study highlighted the extent to which the documentation of innovations implemented in 2013 under the JOLISAA project helped to track down more or less exhaustively innovations in parboiling that occurred between 2013 and 2021 in the study area. This previous documentation made it possible for us to reduce memory effort for the respondents and to improve the quality and reliability of data collected from these women. In line with the analysis, the present study could also provide reference data to further similar studies in 10 years or less or more. This suggests that, as far as possible, monitoring-evaluation-documentation-learning mechanisms are useful for studying the dynamics and amplitude of innovation, and hence, for progress in a given field.

CONCLUSION

This paper addressed the dynamics and the amplitude of innovation in the agri-food sector in the Republic of Benin. It fills the knowledge gap on these subject matters in the rice value chain, and more specifically in the parboiling of locally produced rice, between 2013 and 2021. The study from which it derived was conducted in the municipality of *Glazoué* in central Benin, which represents one of the two rice production hubs in Benin. The paper took as references, innovations related to rice parboiling that were inventoried under the JOint Learning in Innovation Systems in African Agriculture (JOLISAA) project funded by the EU, between 2010 and 2013. In addition to the data from this reference study, semi-structured and structured interviews were conducted with women rice parboilers, and with managers and other resource persons involved in rice

parboiling in the municipality and elsewhere in Benin. These interviews were reinforced by field visits, observations, photo recordings, and a literature review to build coherent stories around the dynamics and the amplitude of innovations in rice-parboiling in the study area. Data collected were entered into an Excel spreadsheet and then analysed qualitatively and quantitatively. Quantitative analyses involved estimating frequencies, percentages, means, and standard deviations. Qualitative data were summarised in tables, figures, and inserts. The findings indicate that between 2013 and 2021 (i.e. in about 9 years), 8 of the 17 innovations (related to rice parboiling) inventoried under JOLISAA in 2013, underwent up to 23 subsequent innovations, i.e. an average of about three (3) innovations per year. These 23 innovations were mainly technological and technical (65%), followed by organisational and institutional (35%). Each of these innovations took place over an average of two years. 52% of the diagnoses that led to these 23 innovations came from both the women rice-parboilers and their technical and financial partners, which underlines the importance of collaboration and therefore the mixed origin of these diagnoses. 74% of the innovations identified were developed by technical partners, compared with 26% by the women parboilers. Innovations from the women parboilers were predominantly incremental, while those from their technical partners were mainly modular in scope. The incremental nature of the women-parboilers-led innovations shows the importance of technical skills in the development of innovations. Since modular, radical, or architectural innovations are considered more profitable, strengthening the presence of technical partners or innovation brokering specialists could increase the dynamics of these innovations for the benefit of the women rice parboilers. The findings also revealed the absence of genetic or varietal innovation during the study period and the potential disappearance of the use of training videos from the habits of the women surveyed. The importance of continuous documentation of practices and innovations was also demonstrated by this study, which took advantage of JOLISAA's 2013 reference data to track more or less exhaustively innovations that occurred between 2013 and 2021 in parboiling in the study area. Thus, data in this article could also serve as a reference for future similar studies.

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